METHOD AND CONFIGURATION FOR WIRELESS INFORMATION TRANSMISSION
AND INFORMATION SYSTEM FOR A MACHINE EXHIBITING A MULTIPLICITY
OF SENSORS AND/OR ACTUATORS

Cross-Reference to Related Application:

This application is a continuation of copending International
Application PCT/EP00/06217, filed July 4, 2000, which
designated the United States.

Background of the Invention:

    Field of the Invention:

The invention relates to a method for wireless information
transmission between a base station radiating a broadband
radio-frequency signal preferably generated in accordance with
a direct sequence spread spectrum (DSSS) method and a
multiplicity of subscribers or stations. The subscribers are
located at different distances from the base station, the
subscribers coding the received broadband radio-frequency
signal in accordance with the code division multiple access
(CDMA) method according to the information to be transmitted,
modulating it and reflecting it back to the base station. The
base station effecting a signal correlation and demodulation
of the received response signals.

The invention can be used, in particular, for wireless information transmission by radio frequency signals with an industrial robot, an automatic manufacturing machine or automatic production machine that exhibits a multiplicity of proximity sensors/proximity switches and/or actuators. The invention provides for wireless information transmission between a base station with a connected process computer and a multiplicity of subscribers, in this case proximity sensors/proximity switches and/or actuators. The subscribers used can also be, for example, temperature measuring sensors, pressure measuring sensors, current measuring sensors or voltage measuring sensors, micromechanical, piezoelectrical, electrochemical, magnetostrictive, electrostrictive, electrostatic or electromagnetic actuators or indicating elements.

The wireless communication between a base station and a number of subscribers usually takes place via a radio-frequency carrier. It is particularly advantageous in this context if, for the purpose of transmitting information, the subscribers modulate the received radio-frequency carriers and reflect them back to the base station because the subscribers do not need to generate their own radio-frequency signals for information transmission in such a case but use the radio-frequency signal of the base station (backscatter system).

In distinction from the demodulation of an externally generated radio-frequency signal produced in the subscriber itself, the demodulation of the modulated radio-frequency signal is not critical for the base station, for example with

5   regard to the phasing. In comparison with the external generation of the radio-frequency signal in the subscriber, the reflection of the radio-frequency signal is also much more advantageous with regard to the required energy consumption. Overall, a considerable cost reduction is obtained, both with

10   regard to the production costs and with regard to the running operating costs.

From Published, European Patent Application EP 09 15 573 A, for example, such a modulated backscatter system is known in

15   which a broadband radio-frequency signal generated in accordance with the Direct Sequence Spread Spectrum method is radiated from a base station to a multiplicity of subscribers or stations. The subscribers reflect the received signal that is modulated in accordance with information to be transmitted

20   back to the base station.

The use of the multiple access method CDMA (see, for example, the literature references below in this regard) is also generally known. When CDMA is used, however, it is of

25   importance that the power of the signals reflected by the subscribers is approximately of equal magnitude since

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otherwise interfering and inadmissible interferences occur due
to the subscribers transmitting simultaneously. Usually, a
power control system is therefore provided in order to even
out the powers of the signals received by the base station.
5   However, such a power control system is expensive and requires
a two-way exchange of information between the base station and
the subscribers.

Summary of the Invention:

10 It is accordingly an object of the invention to provide a
method and a configuration for wireless information
transmission and an information system for a machine
exhibiting a multiplicity of sensors and/or actuators which
overcome the above-mentioned disadvantages of the prior art
15 devices and methods of this general type, in which
interferences between the subscribers are minimized.

With the foregoing and other objects in view there is
provided, in accordance with the invention, a method for a
20 wireless information transmission. The method includes
radiating a broadband radio-frequency signal between a base
station and a multiplicity of subscribers. The subscribers
are located at different distances from the base station. The
broadband radio-frequency signal received in the subscribers
25 is coded in accordance with a code division multiple access
method according to information to be transmitted resulting in

a coded broadband radio-frequency signal. The coded broadband radio-frequency signal is modulated resulting in a modulated broadband radio-frequency signal. The modulated broadband radio-frequency signal is reflected back to the base station resulting in response signals received in the base station. A signal correlation and demodulation of the response signals received in the base station are performed. During the signal correlation, a time offset of a correlation peak is achieved and a time of the time offset of the correlation peak is calculated in such a manner that the response signals received from the subscribers disposed at a shorter distance to the base station are more attenuated than the response signals of the subscribers disposed at a greater distance from the base station, resulting in automatic compensation for different propagation losses between the subscribers located at the different distances from the base station.

According to the invention, the object is achieved in that during the correlation, a time offset of the correlation peak is achieved and the time of the offset of the correlation peak is calculated in such a manner that the response signals of the short-range subscribers are more attenuated than the signals of the more distant subscribers, which automatically compensates for different propagation losses between subscribers located at different distances from the base station.

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The advantages that can be achieved by the invention consist in that no power control system for controlling transmitting powers is required, which has considerable cost advantages.

5   No two-way information exchange between the base station and the subscribers is required, an information transmission from the subscribers to the base station is sufficient. There is automatic compensation for the propagation loss associated with each subscriber in the sense of evening out the

10 propagation losses of all subscribers.

A wireless communication system is made possible which has a very high subscriber density, with high information transmission density, with high reliability with regard to the

15 data transmission without interfering interferences, with high data integrity and with a short data latency time. The individual subscribers have low complexity, low losses and low power consumption and can be produced inexpensively. Overall, there is a high degree of capability for suppressing

20 interference and frequency-selective fading is reduced in a significant way.

The invention is of great advantage in particular in the case of a network consisting of at least one base station and a

25 multiplicity of subscribers because it allows for high

subscriber density and high signal density and ensures high
accuracy and high reliability during the data transmission.

In accordance with an added mode of the invention, there is
the step of adapting a chipping rate of the broadband radio-
frequency signal emitted by the base station to the different
distances between the subscribers and the base station.

In accordance with another mode of the invention, there is the
step of generating the broadband radio-frequency signal in
accordance with a direct sequence spread spectrum method.

In accordance with a further mode of the invention, there is
the step of adapting a chipping rate of the broadband radio-
frequency signal emitted by the base station to the
propagation loses between the subscribers and the base
station.

With the foregoing and other objects in view there is
provided, in accordance with the invention, a configuration
for a wireless information transmission. The configuration
contains a base station radiating a broadband radio-frequency
signal and has a transmitting device, a modulator/coder
connected to the transmitting device, a receiving device and a
demodulator/decoder with a correlator connected to the
receiving device. A multiplicity of subscribers are located

at different distances from the base station. Each of the
subscribers has a modulation device and an
antenna/backscattering device for receiving the broadband
radio-frequency signal and for reflecting a response signal,
5 coded in accordance with a code division multiple access
method and modulated by the modulation device in accordance
with information to be transmitted. The modulation device is
connected to the antenna/backscattering device. The
correlator of the base station performs automatic compensation
10 for different propagation losses between the subscribers
located at different distances from the base station by
linking a correlation function and a propagation loss to one
another in an inverse relationship.

15 In accordance with an added feature of the invention, the base
station generates the broadband radio-frequency signal in
accordance with a direct sequence spread spectrum method.

With the foregoing and other objects in view there is
20 provided, in accordance with the invention an information
system for a machine having a multiplicity of sensors and/or a
multiplicity of actuators. The information system contains a
base station radiating a broadband radio-frequency signal and
has a transmitting device, a modulator/coder connected to the
25 transmitting device, a receiving device and a
demodulator/decoder with a correlator connected to the

receiving device. A multiplicity of subscribers are located
at different distances from the base station. Each of the
subscribers has a modulation device and an
antenna/backscattering device for receiving the broadband
radio-frequency signal and for reflecting a response signal,
coded in accordance with a code division multiple access
method and modulated by the modulation device in accordance
with information to be transmitted. The modulation device is
connected to the antenna/backscattering device. The
correlator of the base station performs automatic compensation
for different propagation losses between the subscribers
located at different distances from the base station by
linking a correlation function and a propagation loss to one
another in an inverse relationship.

In accordance with an additional feature of the invention, the
sensors are proximity sensors.

In accordance with a further feature of the invention, the
base station generates the broadband radio-frequency signal in
accordance with a direct sequence spread spectrum method.

In accordance with a concomitant feature of the invention, the
machine is an automatic production machine.

Other features which are considered as characteristic for the invention are set forth in the appended claims.

Although the invention is illustrated and described herein as embodied in a method and a configuration for wireless information transmission and an information system for a machine exhibiting a multiplicity of sensors and/or actuators, it is nevertheless not intended to be limited to the details shown, since various modifications and structural changes may be made therein without departing from the spirit of the invention and within the scope and range of equivalents of the claims.

The construction and method of operation of the invention, however, together with additional objects and advantages thereof will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

Brief Description of the Drawings:

Fig. 1 is an illustration of a configuration for wireless information transmission between a base station and a multiplicity of subscribers according to the invention;

Fig. 2 is a block diagram of sensor as an example of a subscriber with an associated base station; and

Figs. 3 and 4 are two loss/time diagrams for explaining a method according to the invention (not true to scale).

5   Description of the Preferred Embodiments:

In all the figures of the drawing, sub-features and integral parts that correspond to one another bear the same reference symbol in each case. Referring now to the figures of the drawing in detail and first, particularly, to Fig. 1 thereof,

10 there is shown a configuration for wireless information transmission between a base station 2 and a multiplicity of stations or subscribers 1.1, 1.2, 1.3 ... 1.s, preferably sensors or actuators (backscatter system). Communication between the base station and the subscribers 1.1 to 1.s is

15 preferably in accordance with the direct sequence spread spectrum (DSSS) method, i.e. the base station 2 sends a broadband radio-frequency signal to the subscribers 1.1 to 1.s.

20 Where "radio-frequency signals" have been mentioned above, this also includes very high frequency signals, extremely high frequency signals, ultrahigh frequency signals and superhigh frequency signals, of course.

25 With respect to the spread spectrum transmission technique, reference is made to the textbook titled "Digitale

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Kommunikation über Funk: Methoden und Meßtechnik digitaler
Nachrichtenübermittlung" [Digital Communication By Radio:
Methods and Measuring Technology Of Digital Information
Transmission] by P. Hatzold, Franzis Verlag, 1999, page 171 to
5   182.   Spread spectrum signals cause the emissions to have a
wide bandwidth.   An eminent characteristic of these signals is
that the radio-frequency bandwidths used for their
transmission is much greater than the symbol rate of the data
signal.   This leads to the transmitting power being
10   distributed over a wide frequency range, and thus to an
extremely low spectral power density.   As a result, it is
difficult to detect the signals in the noise.   The capacity,
i.e. the amount of information that can be transmitted,
increases linearly with the bandwidth.   Another characteristic
15   of these signals is their great similarity to white noise that
comes from the baseband signals being linked to pseudo random
sequences.

In principle, the bandwidth can be spread in two ways.   Either
20   the carrier frequency is changed in accordance with a pseudo
random sequence during the period of transmission of a symbol
(fast frequency hopping), or the symbols to be transmitted are
combined with a Pseudo Random Bit Sequence (PRBS, spreading
code) of much higher clock rate (DSSS) before they modulate
25   the radio-frequency carrier.   Naturally, the pseudo random
sequence used in each case must be known to the subscribers in

both cases so that they can correct the received frequency to the random sequence of the transmitter in the case of fast frequency hopping or filter the signal intended for them from the noise spectrum by correlation techniques in the case of DS

5   Spread Spectrum. The individual subscribers 1.1 to 1.s of the network respond to the base station 2 and reflect response signals A, provided with corresponding information (for example detected sensor information) and coded in accordance with the code division multiple access (CDMA) method and

10   modulated, back to the base station 2.

With respect to the CDMA method, general reference is made to the technical compendium titled "Informationstechnologie von A-Z", Aktuelles Nachschlagewerk für die berufliche Praxis

15   [Information Technology From A-Z, Up-To-Date Work Of Reference For Professional Practice], volume 1, Interest GmbH, Augsburg, February 1999. This multiple access method is based on the code division multiplex (CDM) method and enables all users of a network to respond at the same frequency. Identification of

20   and distinguishing between the individual users 1.1 to 1.s takes place due to the fact that the backscattered signals are combined with an individual pseudo random code for each subscriber. The response signals of all users, which are equipped with different codes, are superimposed on one another

25   and result in a broadband spread spectrum that is wider than the original signal by the code-dependent spreading factor.

The spreading factor is a measure of how many signals can be added together.

The pseudo random sequence (spreading code) is specified

5　separately in the sense of a code division (allocation of a local address) for each subscriber 1.1 to 1.s and is known to the base station.

Fig. 2 shows a sensor, particularly a proximity sensor, as an

10　example of the station or subscriber 1.1 with the associated base station 2.　The sensor 1.1 exhibits an antenna/backscattering device 3, a modulation device/coding device 4 and a sensor head 6.　Other units of the sensor 1.1 that are not of interest here, for example a power unit

15　suitable for supplying power, are not shown.　Apart from the units that are not of interest here, the base station 2 exhibits a modulator/coder 8, a transmitting device 9, a receiving device 10 and a demodulator/decoder 11.

20　The sensor 1.1 receives the broadband radio-frequency signal s(t) radiated by the base station 2.　The sensor head 6 supplies detected sensor information S to the modulation device/coding device 4, which generates corresponding modulation signals C and supplies them to the

25　antenna/backscattering device 3.　From response signals A received via the radio link antenna/backscattering device 3 -

the receiving device 10, the demodulator/decoder 11 (including
a correlator 15) of the base station 2 forms the sensor
information S transmitted by the individual subscriber, in
this case the sensor 1.1.

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At the same time, the base station 2 receives all other
signals of the other subscribers as aggregate noise power.
The aggregate noise power can be much greater than the
received power of the signal to be received. The individual
signal only apparently drowns in the noise of the aggregate
noise power.

In a cellular system having a number of subnetworks (cells),
where each subnetwork exhibits a base station and a number of
subscribers, communication between base stations and
associated subscribers also takes place, for example, in the
CDMA method, a different code sequence being allocated to each
subnetwork.

20   As an alternative, communication between base stations and
associated subscribers in a cellular system can also take
place, for example, in the frequency division multiple access
(FDMA) method, a different frequency being allocated to each
subnetwork.

25

The essential concept of the invention is automatic
compensation for different propagation losses between
subscribers or stations 1.1 to 1.n that are located at
different distances from the base station 2. The starting
5   point is the consideration that the above-mentioned
communication method with CDMA and correlation is advantageous
in the sense that the base station no longer needs to be
synchronized to the response signals of the subscribers since
there is already a phasing which is perfect apart from the
10   propagation time of the signals. The time required by the
signal returning to the base station 2 depends on the distance
between the base station and the individual subscribers, i.e.
there is a direct connection between the arrival time of the
signal and the distance, and thus the propagation loss, since
15   the latter depends approximately on the distance. The closer
the subscriber is located to the base station, the stronger
the received signal and the earlier it will arrive.

The invention produces restrictions with respect to the signal
20   transmission rate and the time offset which can be achieved by
the correlation - called offset of the correlation peak in the
text that follows, so that the correlation function, on the
one hand, and the propagation loss, on the other hand, can be
linked to one another in an inverse relationship. If the
25   propagation loss in the area of interest is inversely matched
to the offset of the correlation peak, it will produce a flat

amplitude response, (i.e. more attenuated) after the

correlator even in the short range. If it is desired to

maintain the good signal/noise ratio in the short range, this

can be made possible by another correlator.

5

From the prior art, synchronization curves in the form of S

curves, which can be generated by offsets of correlation peaks

which can be adapted in many ways (inversely) to loss curves,

are known in conjunction with code synchronization loops.

10 Furthermore, offsets of correlation peaks can be generated

which reduce the received energy of the subscribers in the

short range by combining different correlation functions (with

different offsets) and/or using altered reference functions

(for example with a three-step sequence). In this connection,

15 it is appropriate to divide the subscribers 1.1 to 1.s into

different zones in dependence on their distance from the base

station 2 in order to use in this manner different measures

for the individual zones which reduce the interferences

occurring in the communication between the subscribers 1.1 to

20 1.s and the base station 2.

In particular, the DSSS chipping rate of the signal radiated

by the base station is adapted to the propagation loss curve

that, in turn, depends on the frequency and the range of

25 distances of interest. The chipping rate is defined as $1/T_c$

where T_c is the chip period and corresponds to the reciprocal of the PRBS clock rate.

The time of the offset of the correlation peak can be
5 calculated adaptively in dependence on the configuration actually present, containing at least one base station 2 and a multiplicity of the subscribers 1.1 to 1.s and an algorithm running automatically can optimize this either continuously or at fixed time intervals or once on installation of the
10 configuration.

The invention will be explained in greater detail with an actual example and referring to the loss/time diagrams according to Figs. 3 and 4. A configuration is given which contains the base station 2 and the multiplicity of
15 subscribers 1.1 to 1.s within a range of 1 to 4 m distance, communication between the base station and the subscribers taking place by use of DSSS at a carrier frequency of 2.4 GHz and a chipping rate of 40 MHz (25 ns period). The close-range
20 signal path (1 m distance) is 2 m so that the first signal returns after $t_1 = 6$ ns attenuated by 60 dB (referred to the transmit level, Rayleigh factor 1.5). The long-range signal path (4 m distance) is 8 m so that the second signal returns after $t_2 = 24$ ns attenuated by 78 dB (referred to the transmit
25 level). The difference between the two propagation losses is

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disadvantageously relatively high at 18 dB, which leads to
interfering interferences.

Placing the correlation peak on $t_2 = 24$ ns - as shown in Fig. 3
- has the result that the first signal is additionally
attenuated by a further 12 dB whereas the propagation loss of
the second signal remains unchanged, i.e. a loss of 78 dB in
the second signal is now contrasted with a loss of 72 dB in
the first signal. The difference between the two propagation
losses has now been reduced to 6 dB.

Placing the correlation peak on $t_3 = 27$ ns - as shown in Fig. 4
- has the result that the first signal is additionally
attenuated by a further 3.5 dB (see 15.5 dB), whereas the
propagation loss in the second signal is only increased by 0.3
dB, i.e. a loss of 78.3 dB in the second signal is now
contrasted with a loss of 75.5 dB in the first signal. The
difference between the two propagation losses has now been
advantageously reduced to 2.8 dB. Further optimizing in the
direction of the least possible difference between the
propagation losses is possible by further shifting the offset
of the correlation peak.

Regarding the general operation of a code tracking loop,
reference is made to the textbook "Spread Spectrum CDMA
Systems for Wireless Communications" 1997, Artech House, Inc.

Boston, London, pages 120 to 128, particularly page 124 to

126, chapter 3.2.3 Tau Dither Early-Late Noncoherent Tracking

Loop with figures 3.14 and 3.15. This discloses a method and

a configuration for correlating a broadband radio-frequency

5 signal modulated by the spread-spectrum transmission

technique, using a Tau Dither Early-Late Code Tracking loop

for code detection and code tracking.